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WINTER FIELD USE OF CO_2 FREEZING TO OBTAIN CORE SAMPLES OF STREAM SEDIMENTS

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Environmental Protection Agency
College, Alaska

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ARCTIC ENVIRONMENTAL RESEARCH LABORATORY
COLLEGE, ALASKA 99701

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by

Frederick B. Lotspeich

and

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CONTENTS

	PAGE
INTRODUCTION	1
EQUIPMENT AND PROCEDURE	3
RESULTS AND DISCUSSION	11
LITERATURE CITED	18

LIST OF FIGURES

NUMBER		PAGE
1	Equipment necessary for winter use of CO_2 sampling procedure.	4
2	All equipment needed for this procedure includes sampling gear, ice auger, "Akhio" and snow machine.	5
3	A core removed from under about 5 feet of ice with flowing water between the ice and top of sediment.	6
4	The CO_2 sampling technique in action under winter conditions.	8
5	Employment of equipment on hand to remove a frozen core.	9
6	A core of frozen gravel removed from under the ice by the CO_2 freezing technique.	12
7	A core of sand and fine gravel obtained by CO_2 freezing.	13
8	A core about 3 feet in length representing a wide sedimentary range, from fine gravel to pebble size particles.	14
9	Particle size versus accumulative percent for several representative cores collected during late winter of 1973.	16

INTRODUCTION

Any study of streams, whether the emphasis is on biology or stream dynamics, must consider the sediments because they are of vital importance in understanding many stream phenomena. Phillips (1973) clearly points out how stream substrates are important to salmonids, a group requiring clean gravel as spawning areas. In many of Alaska's streams, such gravel substrates predominate.

Sand-bottomed streams have been studied in temperate climates and much of their dynamic nature is understood; however, gravel-bottomed streams have been somewhat neglected. Although it has long been observed that salmon spawning requires a gravel bottom, little quantitative data on why and how gravel substrates influence productivity are available. This absence of data is at least partly caused by a lack of accurate substrate sampling procedures. Development of such procedures must precede more fundamental studies of sediment-biology interrelationships. The ideal sediment samples would be truly representative of that portion of the stream from which it is extracted. Several sampling techniques, from narrow spades to large cylinders inserted in the gravel with hand-picking in place, have been used, but all result in inaccurate samples as much of the fine material is lost.

An apparently superior method for sampling sediments has been developed and described by Walcotton (1973). Basically this method consists of extracting a frozen core of _in situ_ material from the depth to which the sampler can be inserted. A rigid copper pipe is forced into the stream bottom, then a smaller open-ended flexible copper tube is placed inside the longer pipe. Liquid CO_2 is injected through this smaller tube to the bottom of the larger one. When the CO_2 is injected, it cools the outer

tube rapidly, freezing the adjacent sediments in position. All material within the frozen core is retained, including water, all sizes of sediment, and occasionally living organisms.

A similar procedure, using liquid nitrogen as the cooling agent, has been described by Stoker and Williams (1972). (This method avoids occasional clogging by solid CO_2.) These workers also used a power winch to remove the frozen core from the stream bed, a practice we have considered but not tested.

Since most streams of Alaska are ice-covered for a large part of the year, this procedure was tested under winter conditions to fulfill a need in an existing project. The equipment was fabricated and the procedure tested during the summer of 1972. It operated just as described, with the limitations and capabilities noted by Walcotton. This report describes the equipment, procedures, modifications and results of winter use.

EQUIPMENT AND PROCEDURE

Our original equipment followed Walcotton's design closely because of frequent communication with him during his early testing of the technique, and was found satisfactory for summer use or under non-ice conditions. However, for winter use several modifications were made on his original design. Because longer tubes were required, the male portion of a brass union was brazed to the upper end of the pointed tube; the other part of the union was brazed to an 8-10 inch tube, which ended in a "T" (Figure 1). Intermediate sections of the same tubing (about 4 feet in length) were provided with similar unions. This permitted the length of the sampler to be quickly extended, in 4-foot sections, when a longer tube was needed for use under thick ice and/or deep water. The inner tube was also lengthened but without sectioning. All the equipment was easily carried on an "Akhio" sled towed by a snow machine. Figure 1 shows a general view of the entire set of sampling equipment situated in position at the hole, which was bored by the ice auger shown in the background. The ice here was 3 to 4 feet thick. Figure 2 shows the snow machine with the "Akhio" in the foreground and the sampler emplaced prior to freezing. Figure 3 shows the core extracted and the ice coated union joining the two sections.

These modifications enabled sampling under ice but did introduce some minor problems which effected slight procedural changes from those suggested by Walcotton. A new problem was the increased flexibility of the outer, rigid copper tube when it was lengthened to 8 or 12 feet. This prevented putting much force on the sampler during emplacement; hence, it could not penetrate consolidated sediments. However, no problem was found in sampling freshly deposited, unconsolidated sediments even when three sections

Figure 1. Equipment necessary for winter use of CO_2 sampling procedure.

Figure 2. All equipment needed for this procedure includes sampling gear, ice auger, "Akhio" and snow machine.

Figure 3. A core removed from under about 5 feet of ice with flowing water between the ice and top of sediment. Total depth of sediment, water, and ice is about 7 feet.

of rigid tubing were used. Walcotton suggests that 2 or 3 samples could be frozen with 15 lbs of CO_2; however, to reliably get a sample under ice and greater water depth with the extended tubes required more CO_2. After some experimentation, including several failures to get a sample, the procedure finally developed was to expend one 15 lb. bottle of CO_2 per sample. Such a rate of expenditure of gas may appear somewhat extravagant but is actually inexpensive when all other costs are considered. Figure 4 shows the sampler in operation using about 8 feet of rigid tubing. Notice here that the inner flexible tube extends several feet beyond the vertical tube. This additional portion permits the same inner tube to be used when another section of rigid tube is needed; such use of one long tube eliminates the need to carry inner tubes of several lengths. Note also that the operator is holding the inner tube with his hand instead of tying it as suggested by Walcotton; either way is satisfactory, but securing of this tube is a requirement or it will blow out of the sampling tube when CO_2 is expended.

Once the core is frozen in place, it becomes something of a problem to extract it from the stream bottom. Several approaches are available. For summer use and with short cores, the core was simply pulled out by lifting with bent arms under the "T" of the tube. This requires some vigorous pulling and the risk of a wrenched back is always present, especially in uncertain footing. Walcotton is presently experimenting with a tripod with a light weight block-and-tackle. Figure 5 shows a method using the equipment normally carried on such a sampling trip. The shank of a heavy ice chisel was lashed to the "T" handle and used the CO_2 cylinder as a fulcrum of a second class lever. Such an arrangement gave substantial mechanical advantage and enabled safe removal of several long cores when straight lifting was unsuccessful. When taking core samples during

Figure 4. The CO_2 sampling technique in action under winter conditions. Expenditure of CO_2 in this scene is probably more than required but, to get a reliable core, we found that a rapid rate of CO_2 emission produced maximum length and diameter of cores.

Figure 5 Employment of equipment on hand to remove a frozen core. Note the water over the ice, a common occurrence when holes are bored in river ice and wnich contributes to uncertain footing (later winter, 1973).

warmer weather, they must be removed within a few minutes or the water may thaw the material immediately adjacent to the tube and it may slip out without core.

In winter, cores are easily preserved in their frozen state, can be handled while on the tube, and transported to the laboratory for further processing. Once in the lab the tube can be filled with warm tap water which quickly thaws the core around the copper tube and it is easily slipped out. The intact core can then be allowed to thaw or be stored in a freezer for future work. Longer cores can be cut into sections where definite changes of material occur, placed in plastic bags, and stored frozen until particle size analysis can be run on all cores collected during the winter season. The analyses made of cores taken during our evaluation phase consisted of sieving through a set of sieves using the international system with square holes based on 1 mm as a standard. Sizes ranged downward by halving each sieve to .062 mm and upward by doubling to 16 mm. A final screen of 22 mm was added to collect the larger gravel. Sieving was by a hand-operated mechanical shaker secured to a lab bench top.

RESULTS AND DISCUSSION

Three cores, illustrating a range of particle-size distribution, are presented in Figures 6, 7, and 8. It is obvious that the material in Figure 6 is principally gravel that appears to be uniformly distributed with depth. The cores shown in Figures 7 and 8 are composed of much smaller particles, with Figure 7 showing very uniform distribution with depth until a gravel substrate is encountered. Figure 8 shows a mixture of material with the bulk of material in the sand and fine gravel size range. Such a view showing the range in size of material that is reliably sampled by this technique illustrates the usefulness of this method and permits field interpretation of changes in substrate with depth and position.

Figure 9 is a graphical portrayal of particle-size distribution from a sieve analysis of the cores shown in Figures 6 (core #30), 7 (core #29), and 8 (cores #27A and 27B). In this Figure, size is given on the "x" axis on a logarithmic scale, and quantity as percent accumulation on the "y" axis. Such a diagram clearly shows that the appearance of the cores, as removed from the stream bed, reflects differences in size distribution. The curve for core #30 is significantly different from the other three and contains no material finer than 0.125 mm in diameter. Moreover, most of the material (71 percent) is larger than 4 mm.

The curve for core #29 is quite different from that for core #30 and verifies the uniform appearance of the core material as removed from the stream bed. Only about 22 percent of this core is greater than 8 mm in diameter and remains low (a total of 28 percent) down to 0.5 mm. The bulk of the material in this core, about 78 percent, is <0.5 mm in diameter.

Curves for cores #27A and 27B were taken from the core shown in Figure 8. This core was divided into two sections after being trans-

Figure 6. A core of frozen gravel removed from under the ice by the CO_2 freezing technique.

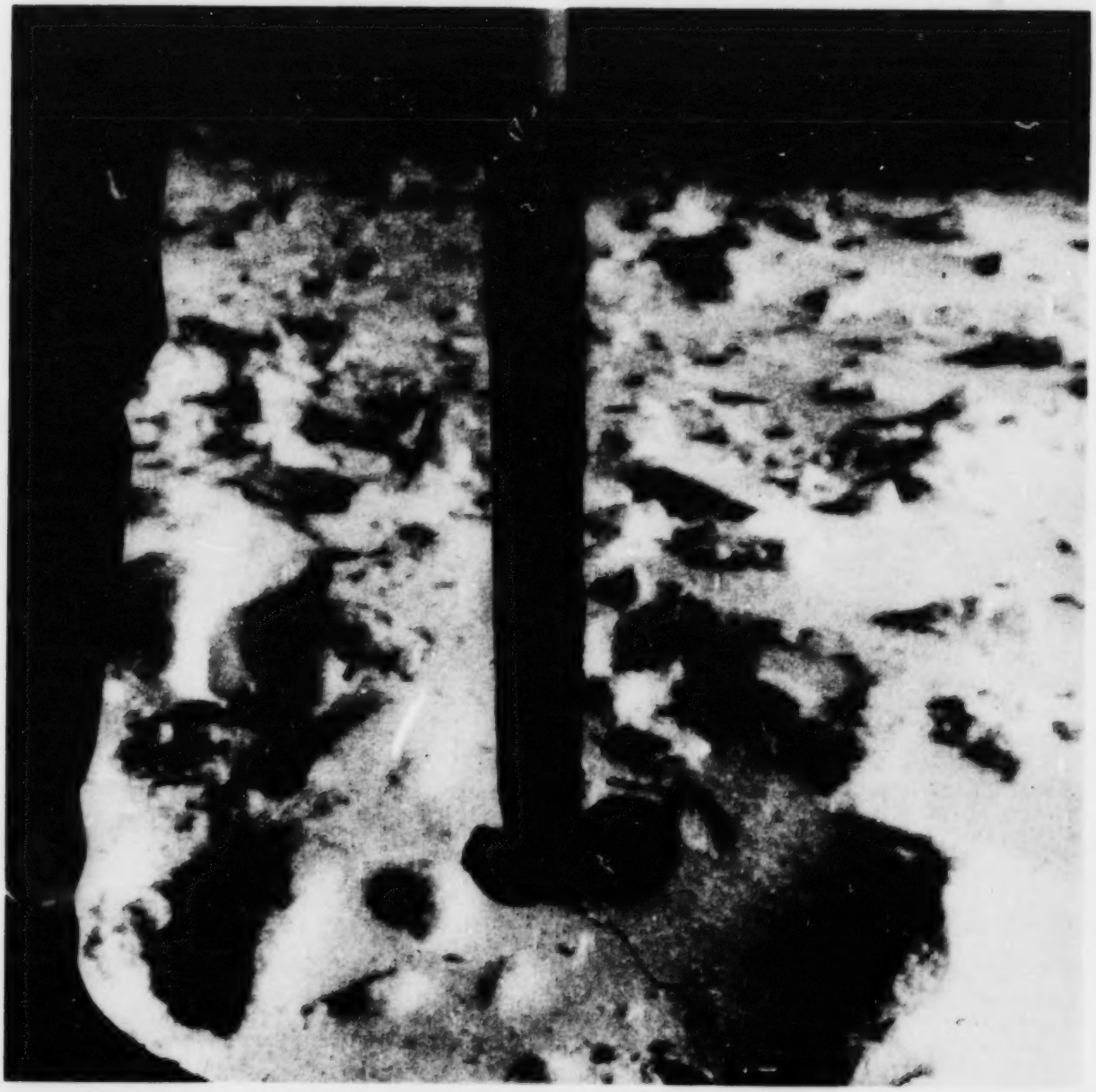

Figure 7. A core of sand and fine gravel obtained by CO_2 freezing. Note here the pebbles at the bottom; this represents dramatic changes in sedimentation from a stable gravel substrate to a more ephemeral rapid sedimentary regimen (length of core is about 15 inches).

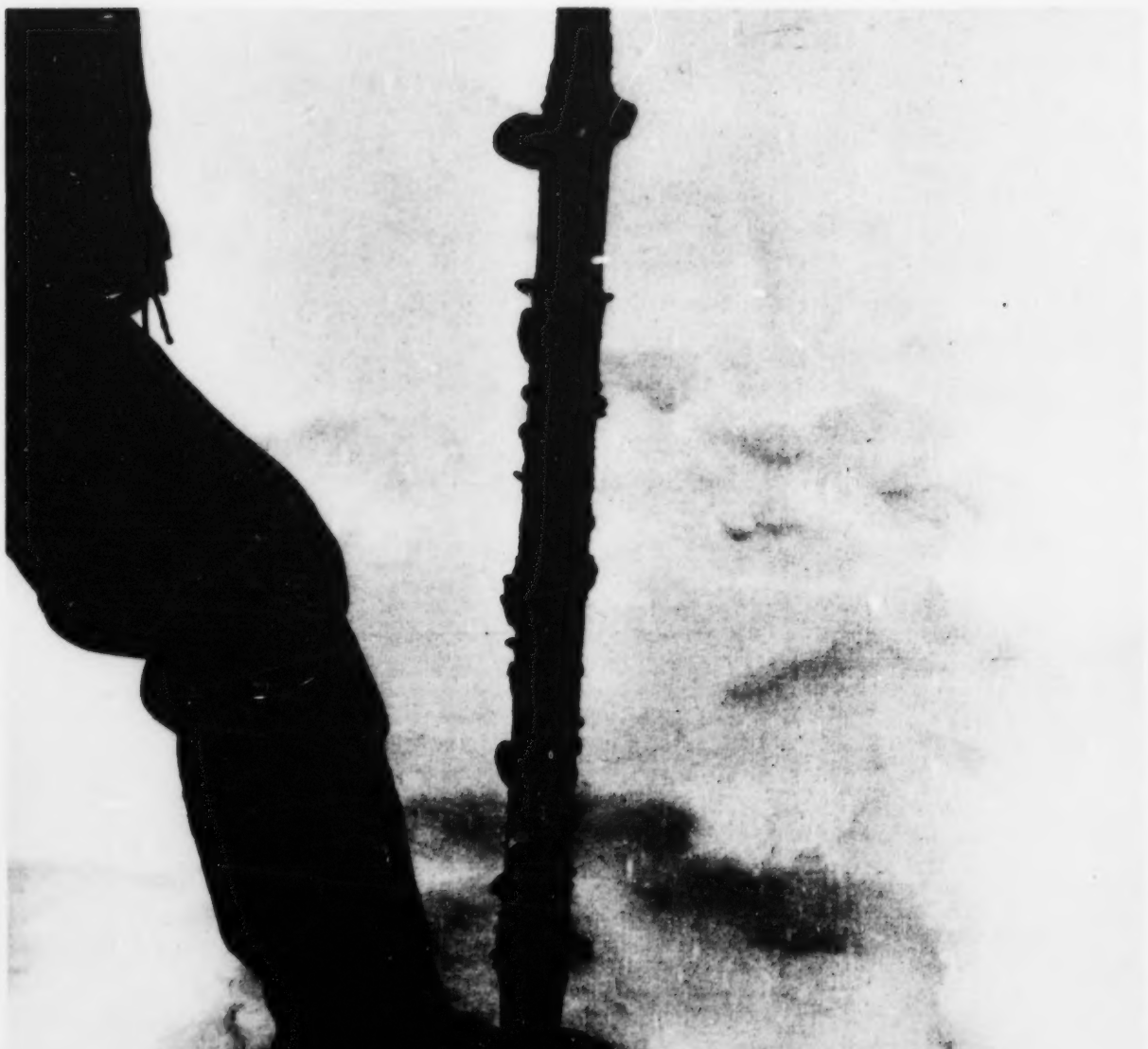

Figure 8. A core about 3 feet in length representing a wide sedimentary range, from fine gravel to pebble size particles.

ported and stored in the lab. Such sectioning illustrates another advantage of this technique; it permits quantitative analysis of portions of the substrate without mixing of adjacent sections. Although these curves are similar in shape, the material in #27A is clearly much finer, with 97 percent being finer than 1 mm and 57 percent finer than 0.25 mm in diameter. The material in core #27B is coarser with 28 percent less than 0.5 mm in diameter.

This freezing procedure permits a nearly undisturbed sample to be withdrawn from a stream bed and allows the investigator to make preliminary field interpretation at that time. It also permits quantitative lab analysis of an entire core or individual section where discontinuities occur, with reliable assurance that contamination by adjacent sections or loss of some component is negligible. Both the field interpretation and interpretation of graphs such as Figure 9 enable an investigator to draw important conclusions about the characteristics of the material whether it is a biological or river mechanics study. A substrate such as that shown by the curve for core #29, will be vastly different in physical properties from that shown in the other three curves and may greatly affect the biology of a stream.

The freezing technique reported here allows a core to be taken at least 84 cm long weighing at least 900 grams. These samples can be considered quite representative of the actual bed material because of minimal disturbance during sampling activities, although there is no such thing as absolute non-disturbance.

As the length of the sampling tube increases, the flexibility also increases which may prevent penetration into compacted material. However, for the unconsolidated material sampled here, a tube length of 10 to 12 feet can be used. More work is needed on the sampling of consolidated

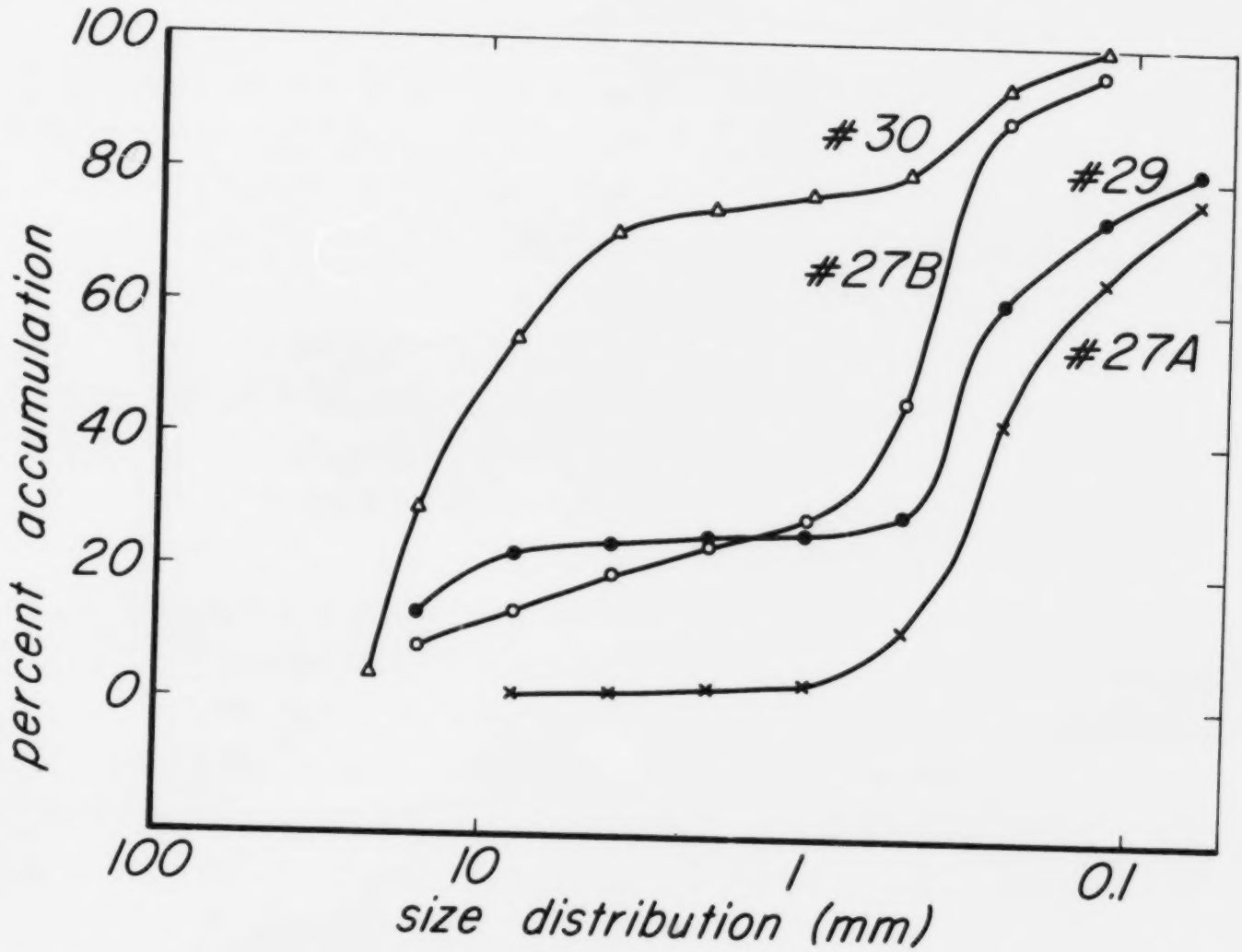

Figure 9. Particle size versus accumulative percent for several representative cores collected during later winter of 1973.

sediments using this procedure. Removal of the frozen core also introduces problems but this can be overcome by mechanical devices such as a tripod and block-and-tackle.

A final point regarding any substrate sampling procedure or program; it becomes highly desirable, even mandatory, that the program be under the field supervision of the most qualified person available. This will decrease the total number of samples, while improving their quality as they better represent a given physical or biological parameter. No amount of subsequent analyses, whether in the field or in the lab, will enhance the final outcome of a program if the samples do not represent what is under study. The highest qualified technician is seldom capable of directing the location of sampling stations simply because he does not have the training or experience to understand the systems under study. It may seem uneconomical to have the highest paid or valuable person directing field sampling, but it will result in higher reliability and credibility of results. Optimum sampling sites are best selected by a person who thoroughly understands the interrelationships of the system under study. Once the sites are selected, this freezing procedure should aid the investigator in getting representative samples from which to get reliable analyses.

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